IHEP 1.3 GHz SRF TECHNOLOGY R&D STATUS*

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Abstract

1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the ILC and future XFEL and ERL projects in China. With the aim to develop 1.3 GHz SRF technology, IHEP has started a program to build an SRF Accelerating Unit. This unit contains a 9-cell 1.3 GHz superconducting cavity, a short cryomodule, a high power input coupler, a tuner, a low level RF system etc. This program also includes the SRF laboratory upgrade, which will permit the unit to be built and tested at IHEP. The unit will be used for the 1.3 GHz SRF system integration study, high power horizontal test and possible beam test in the future. In this paper, we report the recent R&D status of this program. The first large grain low-loss shape 9-cell superconducting RF cavity made by IHEP reached 20 MV/m in the first vertical test. The prototype tuner and LLRF system were tested. The first 1.3 GHz high power input coupler fabrication was finished and the cryomodule is under fabrication. Several key SRF facilities (CBP, BCP, HPR, optical inspection camera, pretuning machine etc.) for 9-cell cavity processing were successfully commissioned and in operation.

INTRODUCTION

1.3 GHz superconducting radio-frequency (SRF) technology is one of the key technologies for the International Linear Collider (ILC) and future XFEL and ERL projects of China. With the aim to develop this technology, IHEP has started a program to build an SRF Accelerating Unit within ILC collaboration [1, 2, 3].

The SRF Accelerating Unit contains a 9-cell 1.3 GHz superconducting cavity, a short cryomodule, a high power input coupler, a tuner, and a low level RF (LLRF) system. The unit can undergo beam tests and can be used as the booster for an SRF linac.

The R&D goals of the program are:

- Cavity gradient of 25-35 MV/m with $Q_0 > 8\times10^9$ for the vertical test, and 20-31.5 MV/m with $Q_0 > 1\times10^{10}$ for the horizontal test;
- 1 MW (5 Hz, 1.5 ms pulse, TW) power through the high power input coupler in conditioning tests; 300 kW (5 Hz, 1.5 ms pulse, SW) power for the horizontal test;
- LLRF phase stability 0.1°, amplitude stability 0.1 %;
- Labs and facilities capable of the 9-cell cavity processing, pretuning, vertical tests and horizontal tests.

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LOW LOSS LARGE GRAIN CAVITY

The combination of the low-loss shape and large grain niobium material is an alternative to achieve higher gradient and lower cost for ILC 9-cell cavities, and will be essential for the ILC 1 TeV upgrade.

Recently, a KEK low-loss shape fine grain 9-cell cavity reached 40 MV/m [4] and a DESY TESLA large grain 9-cell cavity reached 45 MV/m [5]. 45-50 MV/m gradient demonstration of the electro-polished low-loss shape 9-cell cavity, especially with large grain material, is foreseen in the next few years.

A low-loss shape 9-cell cavity (IHEP-01, Figure 1) without HOM couplers using Ningxia large grain niobium was fabricated and processed (CBP + BCP) at IHEP. The first vertical test was made at KEK. 20 MV/m was achieved with strong field emission [6]. After removing almost all the defects with CBP (tumbling) machine, the second test was performed at JLAB [7].

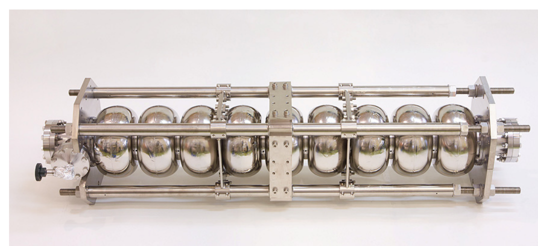

Figure 1: IHEP-01 low-loss large grain 9-cell cavity.

The low-loss shape large grain 9-cell cavity with full end groups (IHEP-02) is also under fabrication. We will test it at FNAL in early 2012. This cavity will be installed into the cryomodule to make horizontal test at IHEP.

HIGH POWER INPUT COUPLER

With the successful fabrication technologies developed for the high power input coupler of the BEPCII 500 MHz superconducting cavity, the 1.3 GHz high power input coupler is designed based on the KEK STF baseline coupler [8] with two TRISTAN type windows.

After careful RF, thermal and mechanical simulation and design, we finished brazing the warm and cold windows and other parts (Figure 2) and finally the whole coupler (Figure 3). The high power test and conditioning will be done soon. In the fabrication, plating copper on bellows was the most difficult. The plating usually volatilized or some bubbles appeared on the plating layer after brazing in the furnace.

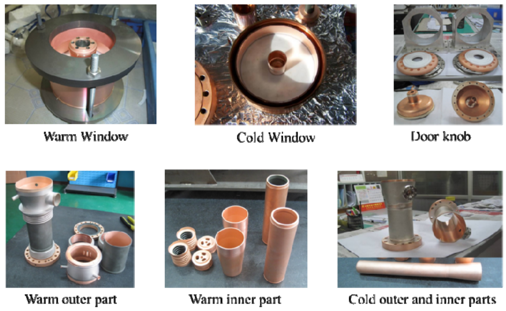

Figure 2: High power input coupler parts.

Figure 3: High power input coupler (warm and cold part).

TUNER

The KEK slide jack tuner [9] is chosen for the design reference because of its large stiffness, robust performance and simple mechanism. The tuner will be set in the middle of the cavity Ti helium vessel. A stepper motor (Phytron VSS-UHVC) inside the cryomodule will be used to drive the tuner.

A prototype tuner was fabricated and installed into the Ti vessel of the MHI-04 9-cell cavity on loan from KEK (Figure 4). The designed cavity axial moving stroke is 4 mm, i.e. 1.2 MHz frequency change, which is enough for the online tuning. Resolution of the rough tuning is estimated to be 0.4 µm. i.e. 120 Hz frequency change of the cavity. Mechanical and electrical interlocks are added to protect the cavity from over tuning.

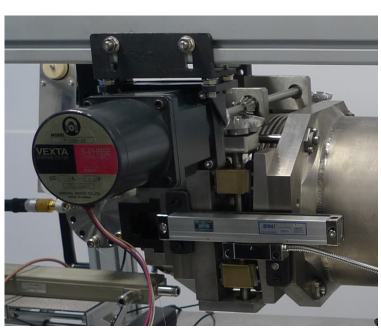

Figure 4: Tuner prototype.

A piezo is used on one side of the tuner for the fast and fine tuning of the cavity to compensate Lorentz force detuning during pulsed operation, especially at a high gradient. The piezo voltage will be 1 kV. The piezo stoke is 4 µm at 2 K, and the corresponding cavity stroke is 2 µm and the frequency range, 600 Hz, which is enough for the Lorentz compensation. However, at room temperature, the piezo stroke is 40 µm, 10 times of that at 2 K. The cavity bandwidth is about 100 kHz at room temperature while the piezo tuning range is 6 kHz, which is relatively small to make an effective piezo test at room temperature.

Since the tuner operates in the 2 K to 4 K environment, low temperature test of the mechanical and electrical system is necessary. We plan to do a liquid nitrogen or liquid helium test for the next step.

LLRF SYSTEM

To test and verify the performance of the digital low level radio frequency (LLRF) and the tuner system, an experiment platform is set up. The frequency of the cavity is locked by the tuner in ± 0.5^{o} (about ± 1.2 kHz) in room temperature. The Digital LLRF system performs well in 5 hours experiment. Results show that the system achieves field stability in amplitude < 0.1 % and phase < 0.1^{o} (peak to peak). It is satisfied to the requirement of the design very well.

The LLRF system consists of several subsystems (Figure 5): the signal and clock subsystem, the RF front-end and back-end model, the AD / DA and FPGA board, the calibration system, the communication subsystem etc.

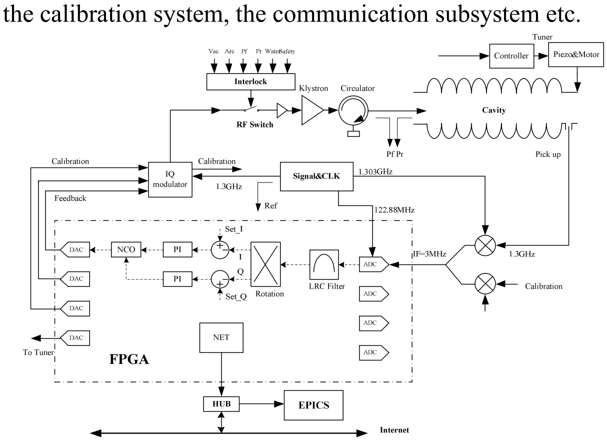

Figure 5: Frame of the digital LLRF test system.

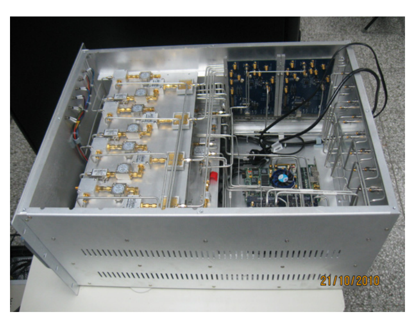

Figure 6: Layers of the LLRF control box.

The LLRF control box (Figure 6) consists of 3 layers, the bottom layer is the power supply model and the FPGA board, the middle layer and the boards suspended in the two sides of the box are used for generating a group of synchronized signal and clock. The analog front-end is placed on the top layer.

SRF INFRASTRUCTURES

IHEP Superconducting RF Lab, built in 2004, is one of the most advanced superconducting RF labs in China. We have treated and tested several low beta single-cell SRF cavities in this lab since 2005. The 1.3 GHz SRF program has significantly improved the IHEP SRF infrastructures and facilities to meet the 9-cell cavity requirement for surface preparation (Figure 7).

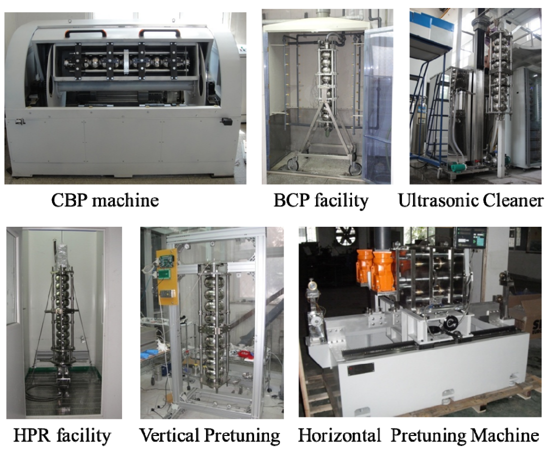

Figure 7: SRF facilities of IHEP.

The CBP machines for single and 9-cell cavities, the BCP facility, the pre-tuning machine, the large ultrasonic cleaner, the HPR system etc. [2, 10] for the 9-cell cavity have been constructed, commissioned and successfully operating at IHEP.

To locate the position of defects and improve surface processing, we have developed a high resolution inspection camera for the 1.3 GHz 9-cell superconducting cavity of IHEP to check the cavity surface [11]. The camera is suitable for single and multi-cell 1.3 GHz superconducting cavities and other different type and frequency cavities. The maximum resolution of the camera system is about 3.6 μm / pixel (Figure 8).

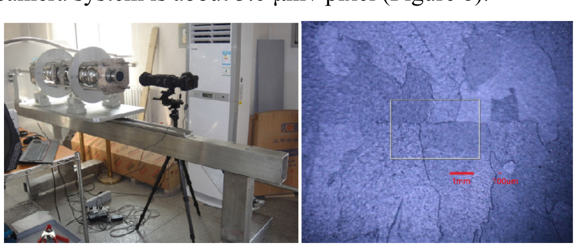

Figure 8: Cavity inspection system.

SUMMARY

IHEP 1.3 GHz SRF R&D is going on well. The cryomodule [3] will start fabrication in 2011. The whole accelerating unit will be integrated in 2012.

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